NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

COST BENEFIT ANALYSIS OF INSTALLING A RECOVERY EXERCISE MODULE (REM) IN A CRUISE MISSILE FOR AN OPERATIONAL TEST LAUNCH

by

Howard Elliott Glassman

June 1987

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Topics considered include: Should the Cruise Missile Project Office (CMPO) continue development of a new redesigned REM; should all test missiles be intentionally destroyed or should the REM be utilized; can the Non-Tactical Instrumentation Kit (NTIK), being developed for the Air Force be a cost effective test procedure for the Sea Launched Cruise Missile?

The conclusion that was reached is that the CMPO should maintain use of the current REM model and cancel plans to redesign the REM. Additionally, REM production and test missile refurbishment should be competed, between several contractors.

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Cost Benefit Analysis of Installing a Recovery Exercise Module (REM) in a Cruise Missile For an Operational Test Launch

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Submitted in partial fulfillment of the requirements for the degree of

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This thesis provides a cost benefit analysis of installing a Recovery Exercise Module (REM) in a Cruise Missile for an Operational Test Launch.

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I. INTRODUCTION

A. AREA OF RESEARCH

The research presented is a "Cost Benefit Analysis of Installing a Recovery Exercise Module (REM) in a Cruise Missile For Operational Test Launches (OTL)."

B. RESEARCH QUESTIONS

The questions to be answered, in this research study, center on one main question. Is it cost beneficial for the Cruise Missile Project Office (CMPO) to have a REM installed in the Sea Launched Cruise Missile (SLCM) for its OTL in order to recover the missile and refurbish it for future use, or is it cost beneficial to destroy the missile and build a replacement?

Subsidiary questions include:

- Is it beneficial to destroy only certain types of missiles, such as the SLCM nuclear land attack missile (TLAM-A)?
- Can the Range Safety System (RSS), required on all test launches, be installed using the Non-Tactical Instrumentation Kit (NTIK) being developed by General Dynamics for use on the Air Force Ground Launched Cruise Missile (GLCM)?
- Is it cost beneficial to build a new redesigned REM to replace the current REM model?

C. DISCUSSION

In response to the growing threat of the Soviet surface fleet and cruise missiles in the early 1970's, the Navy conducted studies to analyze the feasibility of developing a submarine launched cruise missile (Conrow, Smith, and Barbour, p.4, 1982). During this same time period the Air Force was engaged in the development of an Air-Launched Cruise Missile (ALCM). Due to system similarities, cost effectiveness was sought for the project to "maximize subsystem/component commonality and quantity buy, to utilize fully joint test and evaluation, to encourage subsystem/second-source competitive procurement and to otherwise derive maximum benefit from the joint service management of several separable cruise missile programs" (Conrow, Smith, and Barbour, p.12, 1982). Subsequently, reduced costs of missile testing also became a major objective.

"The modular design of the cruise missile permitted the use of a REM which allowed a parachute section to be substituted for the warhead portion of the missile when not needed for that particular test" (Conrow, Smith and Barbour, p.33, 1983). The REM "provides for range safety, override command control, tracking and telemetry." It is also equipped with a receiver decoder, pulse code modulated encoder, S-Band transmitter and C-Band transponder. When the REM is not utilized, a Range Safety System (RSS) must be utilized for safety precautions. The RSS provides for identical functions that exist in the REM, with the exception that it does not provide for missile recovery. (Joint Cruise Missile Project, p.61, 1986)

The original projections concluded that the use of a REM and subsequent refurbishment costs would result in the cost of a recovered missile being 10% of the cost of building a new missile. Both the REM and the missile could be refurbished and reused. Additionally, it was projected that the REM could be utilized for four separate flight tests during its life cycle. However, to date only one of the current REM models has been utilized four times and several have been destroyed in unsuccessful test flights. Moreover, cost of the REMs, as well as REM and missile refurbishment, have dramatically escalated. Hidden costs of the REM system have also been materializing. These include Government Furnished Equipment (GFE) used in missile and REM refurbishment, salvage and recovery costs to return a reusable test missile to the refurbishment facility, additional logistics costs, costs for additional Government personnel to monitor the REM project and new REM development costs. Unfortunately all costs of the system have not yet been identified, and costs of the system are not centrally managed.

This study is intended to identify the costs of this testing procedure and to identify possible alternatives to this system.

D. SCOPE OF THE THESIS

There are several variants of the Cruise Missile that have been developed since the inception of the project. The ALCM, the GLCM, and the SLCM serve many different functions within the defense organization of the United States.

Due to the cost and numbers of missiles involved in the production process, testing of the missile has been extensive. In order to cut back on costs of testing the missile the REM is utilized when conducting many of the OTL's.

This research study will evaluate the cost of utilizing the REM within the Navy's test program. These include the following versions of the SLCM:

1) TLAM-A which is a nuclear armed land attack missile.
2) TASM (Tactical Anti-Ship Missile) which is a version of the ship to ship missile.
3) TLAM-C (Tactical Land Attack Missile - Conventional) which is a conventionally armed land attack missile.

Certain missile configurations, such as the TLAM-D (Tactical Land Attack Missile - Multiple Payload), will not be evaluated. Use of the REM on these versions of the SLCM are not practical due to the size of the payload. Additionally, all test missiles that have been scheduled for total destruction will also be eliminated from this study.

E. METHODOLOGY

The data for this study were collected using a variety of methods. The use of interviews provided personal experience and background for the study. Personal observation at the CMPO and General Dynamics Convair Division (GD/C) helped relate the theory basis of the study to the actual methods used in cost collection. Historical data were collected from a variety of publications on the cruise missile, including the Rand Corporation notes on the JCMP's acquisition history. Current projects on the future use of the REM were collected from documents and reports prepared by GD/C and the CMPO. Finally, collection of actual cost data from Navy contracts covering the previous four years provided the relevant information to complete the analysis.

F. DEFINITIONS AND DESCRIPTIONS

Air-Launched Cruise Missile (ALCM): Strategic missile used by the Air Force as a standoff weapons system to penetrate Soviet air defenses. It is built exclusively by Boeing Aircraft Company (BAC). Its major launch platform is the B-52 bomber, which can carry 20 missiles in its rotary racks. The ALCM can carry a nuclear warhead 1500 nautical miles (NM) (Betts, p.46-47, 1981). With fewer variants then the SLCM and greater production schedules than the SLCM and GLCM, the ALCM has the least cost per missile.

All-Up Round (AUR): Missile airframe, sustainer engine, booster, and guidance system that are contained in a canister used to protect the missile during handling, transporting, and periods of storage.

Ground-Launched Cruise Missile (GLCM): Tactical missile used by the Air Force and NATO forces in Western Europe. It has a 1500 NM range and carries a nuclear warhead. It is launched from truck launching platforms called Transporter Erector Launchers (TELs) (Betts, p.579-580, 1981). The missile is similar in size to the TLAM missiles and uses both an inertial and Terrain Contour Matching (TERCOM) form of guidance system (Hobbs, p.15, 1982).

Non - Tactical Instrumentation Kit (NTIK):

> The GLCM NTIK is a payload instrumentation package compatible with the war reserve W84 payload canister and cabling. It emulates the W84 electronic outputs to the Weapon Control System and provides necessary ballast to maintain missile center of gravity and moment arm characteristics throughout the flight profile. Instrumentation in the NTIK provides for range safety control (including emergency flight termination), radar signature enhancement, and prelaunch/inflight telemetry of real time missile performance data. The NTIK does not provide for recovery of the test missile. To provide NTIK interface with the operational missile, wiring harness modifications and the addition of cable connectors are required. These changes must be incorporated during missile production or recertification. The NTIK consists of W2 wiring harness; special nose cone with S-band, C-band, IFF, and Range Safety System antennas; and the instrumented warhead casing. (Hill and Myers, p.1, 1986)

This is a new system being developed for the Air Force which takes the place of the RSS. Its advantage over the RSS is that the NTIK can be replaced at the field level versus having to send the missile back to GD/C for the RSS installation. (Joint Cruise Missile Project, p.10, 1986)

Recovery Exercise Module (REM): Replaces the missile payload section during OTLs when recovery and refurbishment of the missile is intended. The REM uses a system of three parachutes so that the missile landing will minimize structural damage. The REM also provides for range safety, override command control, tracking and telemetry. Equipment installed in the REM include a pulse code modulated (PCM) encoder, S-band transmitter, C-band transmitter and a receiver decoder. (Joint Cruise Missile Project, p.61, 1986)

Range Safety System (RSS): Similar to the REM in all respects, except that it lacks the parachute recovery mechanisms. Therefore, the RSS is used only on an OTL determined to be a target hit. (Joint Cruise Missile Project, p.61, 1986)

Recertification: Maintenance procedure performed on Cruise Missiles at predetermined intervals. For the TASM it is 30 months and for the TLAM missiles it is 36 months. Recertification includes

> removing payload, maintenance and test of guidance set components, engine removal and replacement, air vehicle test and inspection and rocket motor removal and replacement. In addition specialized processing such as environmental stress screening, inspections, surveys, and engineering order incorporation may be performed as part of the AUR reliability improvement program. (Joint Cruise Missile Project, p.72, 1986)

Refurbishment: Returning a missile and/or a REM to a useable condition after an OTL. It includes replacing expendable parts, calibrating various reuseable parts and repairing the missile airframe. A refurbishment procedure completes all the tests required during missile recertification. Therefore a missile that has been refurbished does not require recertification until the full length of its predetermined maintenance interval expires. (JCM-1963, p.44, 1985)

Sea-Launched Cruise Missile (SLCM): The most diverse of all versions of the Cruise Missile. Nicknamed the "TOMAHAWK" it has been responsible for vast improvements in the Navy's anti-surface, as well as overall, military capabilities in an era that has seen an unprecedented build-up in Soviet Naval forces. There are four different variants of the SLCM all of which can be launched from submarines or surface ships.

The TLAM-A nuclear-armed land attack missile is a tactical missile capable of carrying a 200 kiloton warhead 1500 NM. It is identical in size to the GLCM.

The TLAM-C is a tactical missile that is similar in size to the TLAM-A. However, due to its conventional payload it carries a much larger sized warhead. Therefore, its range is diminished to 700 NM. (Betts, p. 46 - 48, 1981)

The TLAM-D is a tactical multi-warhead missile that is similar in size to the other TLAM missiles. The missile is capable of dropping multiple warheads onto various areas of a given target, usually an enemy airfield.

TASM is a more advanced version of the Harpoon missile (anti-ship missile now used in the fleet), with twice the payload and four to five times the range (300 NM). Due to its missile search capabilities it carries a more sophisticated guidance system than the other SLCM variants. (Betts, p. 46 - 50, 1981)

The Navy is retrofitting the Spruance class (DD963) destroyers, nuclear powered cruisers, battleships, and most submarines to carry the Tomahawk. The Aegis equipped Ticonderoga class (CG47) cruisers and the Arliegh Burke class (DDG-51) destroyers configured to handle the SLCM.

II. BACKGROUND

A. HISTORICAL PERSPECTIVE

The cruise missile is not an innovation of the last several decades. In fact, its roots go almost as far back as the advent of the flying machine. The earliest version dates back to 1915 and efforts made by Peter C. Hewett and Elmer A. Sperry, to build a "flying bomb." Military interest in this new weapon was not significant until the United States entered World War I. At that time, the Navy awarded the Sperry Gyroscope company a research and development contract for the "flying bomb." However, early technology proved inadequate to support the weapon and the program was canceled in 1922. (Werrell, p.7, 1985)

The first successful use of an air breathing missile did not come until World War II. The Germans developed the V-1 buzz bomb and the V-2 (a ballistic missile version of the V-1). Both missiles were similar in range (150 miles), payload (2000 pound warhead) and accuracy (within 8 miles of their target, 80 percent of the time), however, the V-2 was much faster and far less vulnerable to interception by enemy air defenses.

The success of the German V-1 and V-2, along with the advent of nuclear weapons, enhanced U.S. interest in a cruise missile. After World War II the Navy and Air Force made several attempts at building a cruise missile. The Navy undertook the development of a cruise missile that could be launched from the decks of surface ships and submarines. In 1951 the Navy introduced the Regulus missile. It had a range of 500 miles and a speed of 600 miles per hour (mph). In the late 1950's the Regulus II was introduced, with a range in excess of 1000 miles.

During this same period the Air Force began introducing its versions of the Cruise Missile. The Matador, with a 600 mile range and 650 mph speed was tested as early as 1949. The Mace was introduced about 1956. It had a range of 1200 miles and a speed of 650 mph. However, this version used an early form of terrain correlation and map matching guidance system in place of the early ground control guidance system. (De Paz, p.79-80, 1983)

Unfortunately, the early missile systems carried over-sized warheads and had inefficient turbojet engines with heavy power requirements and highly inaccurate guidance systems. The high trajectory flight paths also made these missiles highly vulnerable to enemy air defense systems. Therefore, research and development funds were shifted to the development of the ballistic missile system. (Pfatzgraff, p.6, 1977)

During the 1960's the Air Force still worked on the development of an air breathing missile, but these were to be used as an added dimension to the B-52 bombers. The

Hound Dog missile, with a range of 700 miles and speed of Mach 2, was to be used as a standoff weapon system and the McDonnell Douglas Astronautics Company (MDAC) Quail was to be used as a decoy missile to simulate the B-52 on enemy radar. (De Paz, p.81, 1983)

B. MODERN CRUISE MISSILE DEVELOPMENT

During the 1960's vast improvements were made in the jet engine, guidance system reliability, computer size and capability, as well as terrain contour matching systems (TERCOM). These advances made the development of a cost effective cruise missile a reality. In 1968 the Air Force began development of the Subsonic Cruise Armed Decoy (SCAD). It was to be used with the B-52 bomber to weaken enemy air defense capabilities during a nuclear strike. The Strategic Air Command (SAC) war scenario was to use this new weapon to assist the B-52 in penetrating the enemy defensive zone. However, the Office of the Secretary of Defense (OSD) wanted to utilize the SCAD capabilities as a standoff weapon and a substitute for the B-1 bomber. With the prospect of the loss of the B-1, the Air Force became less than enthusiastic in promoting the new weapon system.

During the early 1960's the Navy saw little need for cruise missiles. Its strategy consisted of using aircraft carriers to make deep strikes into enemy positions and the use of ballistic missiles. The Soviet Union's strategy during this period did include the development of cruise missile systems. In 1967, the launching of a Soviet Styx missile would quickly alter the Navy's policy when the Egyptian Navy, using a Soviet missile system, sank the Israeli destroyer EILAT.

By 1969 the Navy established the Harpoon anti-ship missile program. The airframe would be built by MDAC, and it would carry a 500 pound warhead 60 NM. In 1975 the Harpoon received production go-ahead and by 1979 the Navy had over 1000 missiles in its inventory.

In the early 1970's the Navy conducted studies to determine the feasibility of a submarine launched cruise missile. This effort was carried out under a separate program within the Harpoon project office called Cruise Missile (Advanced).

In 1972 the Strategic Arms Limitation Treaty (SALT) agreement gave the cruise missile an unexpected boost. The treaty limited Sea Launched Ballistic Missiles (SLBM), but placed no limitations on any cruise missiles. The Navy was, therefore, able to convince Secretary of Defense (SECDEF) Melvin Laird that the cruise missile would give the U.S. strategic and tactical weapon systems at relatively low costs. By April 1973 the SLCM established its own project office. (Werrell, p. 146-153, 1985)

In June 1973 the SCAD program had been officially canceled. This, however, was short lived as the program was revived in December, under the name ALCM.

Although the Navy and Air Force were running two separate cruise missile programs there was a great deal of cooperation in the development of key missile components, as OSD stressed system commonality. This process would increase cost effectiveness of the Cruise Missile as DOD could fully utilize quantity buys, test and evaluation requirements, joint planning requirements for future test projects, and subsystem/second-source competitive contract agreements. (Conrow, Smith and Barbour, p.12, 1982) In October 1975 MDAC was selected as the contractor of the guidance system for both the SLCM and the ALCM. In March 1976 GD/C was selected as the SLCM airframe contractor and in May 1976 Williams International Corporation (WIC) was selected as the SLCM engine developer for the ALCM.

Although BAC had been working on the development of the ALCM (BAC was also the airframe contractor for the SCAD) GD/C was pursuing an air-launched version of the SLCM. Since it was not cost effective to use two separate versions of the ALCM, BAC and GD/C were locked into a competitive flyoff in September 1977. BAC's close association with SAC and its projected two year development lead of the ALCM put GD/C at a decided disadvantage. However, GD/C was able to bridge the developmental gap with a more aggressive and cost effective testing program. The missile modular design permitted GD/C to use a parachute REM. The REM was substituted for the warhead portion of the missile when it was not required for a particular test. This allowed GD/C to recover the missile, with minimal damage, and evaluate the individual systems within the missile. The missile was then refurbished and reused for additional tests (Conrow, Smith and Barbour, p.33, 1982). Despite these developments, BAC'S overall understanding of the B-52 and SAC helped it stave off GD/C's advances and was awarded the ALCM contract in April 1980. The decision marked the ALCM's transition from the JCMPO, which was established after the Defense System Acquisition Review Council (DSARC) II decision memorandum in January 1977, to ASD at Wright Patterson Air Force Base (WPAFB) (Conrow, Smith and Barbour, p.61-68, 1982). Besides its establishment of the JCMPO and its assignment to conduct the ALCM competition, the January 1977 DSARC II directed the development of a GLCM using Tomahawk technology.

Again commonality of the Cruise Missile systems as well as its modular design would play a major role in the GLCM's development. Due to the common airframe, engine, and guidance system between the TLAM-A variation of the SLCM and the GLCM, test data obtained from one was directly applicable to the other.

The SLCM has been the biggest benefactor of commonality due to the number of missile variants. The test and evaluation program for each missile variant has benefited from data gathered on OTLs from other missile variants. Even in the case of a test launch for the TASM, which uses a different guidance system than the other SLCMs, data gathered on airframe, engine, and warhead fuzing performance are applicable to the TLAM missiles. Commonality and the modular design also allows the Navy to change the mission of a SLCM by simply changing sections forward of the wings. Therefore, a cruise missile originally built as a TLAM-C can be converted into a TASM. (Conrow, Smith and Barbour, p.33, 1982)

On 1 October 1986 the Air Force/Navy JCMP was redesignated as the Cruise Missile Project (CMP) and assigned as PDA14 within the Naval Air Systems Command.

C. THE RECOVERY EXERCISE MODULE BACKGROUND

The REM was developed by GD/C in 1977. The original intent of the REM was to aid in the recovery of its own test missile and to make it practical to evaluate the effects of a missile launch on the various missile systems/ components. The recovered missile could then be refurbished and equipped for additional test flights or it could be fitted as a fully operational missile. All this could be accomplished at a fraction of the cost for a new missile and in less time than it would take to build a new missile. Therefore, in keeping with the cost effective nature of the cruise missile the Navy decided to use this procedure on the production missile they would be testing.

> For OTL Reliability, the SLCM TEMP directs that the contractor will guarantee that a specified percentage of Tomahawk flight test missiles will successfully fly the specified missile profile from the launch platform to the target. Flight test missiles will be randomly selected from fleet assets by the Navy and returned to the contractor for the REM or RSS installation. Dual government and contractor inspection will occur during this evaluation to ensure that REM installation and minimum checkout is performed to ensure similarity to the present fleet population. The missile will then be returned to the designated launch platform for firing. (Conrow, Smith and Barbour: Appendixes, p.41, 1982)

The REM would permit an estimated 75% of SLCMs to be tested and recovered. The missile could then be refurbished, rearmed, and returned to the fleet (Conrow, Smith and Barbour: Appendixes, p.41, 1982). REMs could also be refurbished and used again if the missile is recovered.

There have been various models of the REM since the program's inception. The earliest model was used by GD/C and the Navy in tests conducted between 1977 and 1983. During this period two test failures were attributed to the REM (see Figure 1). In late 1983 the Navy began using the REM still in current use. It provided for better telemetry data and tracking. During 39 OTLs using the REM between October 1983 and August 1986 seven REMs were expended as a result of problems with the test. This provides for an 18% loss rate (Rosenblatt, 1986).

GENERAL DYNAMICS
Convair Division

DEEP LAUNCH FLIGHT EXPERIENCE

T24:4 (7 Aug 1980) — parachute cover failed due to premature thrust pin shear (flight test data lost over critical period)

- Action: redesign shear pin for 22 psi ult. & tighten up installation procedures

T27:2 (16 Dec 1980) — parachute cover failed at ΔP 14 psid

- Action: all REM vehicles restricted to safe launch depth of 135 ft

(General Dynamics, 1986)

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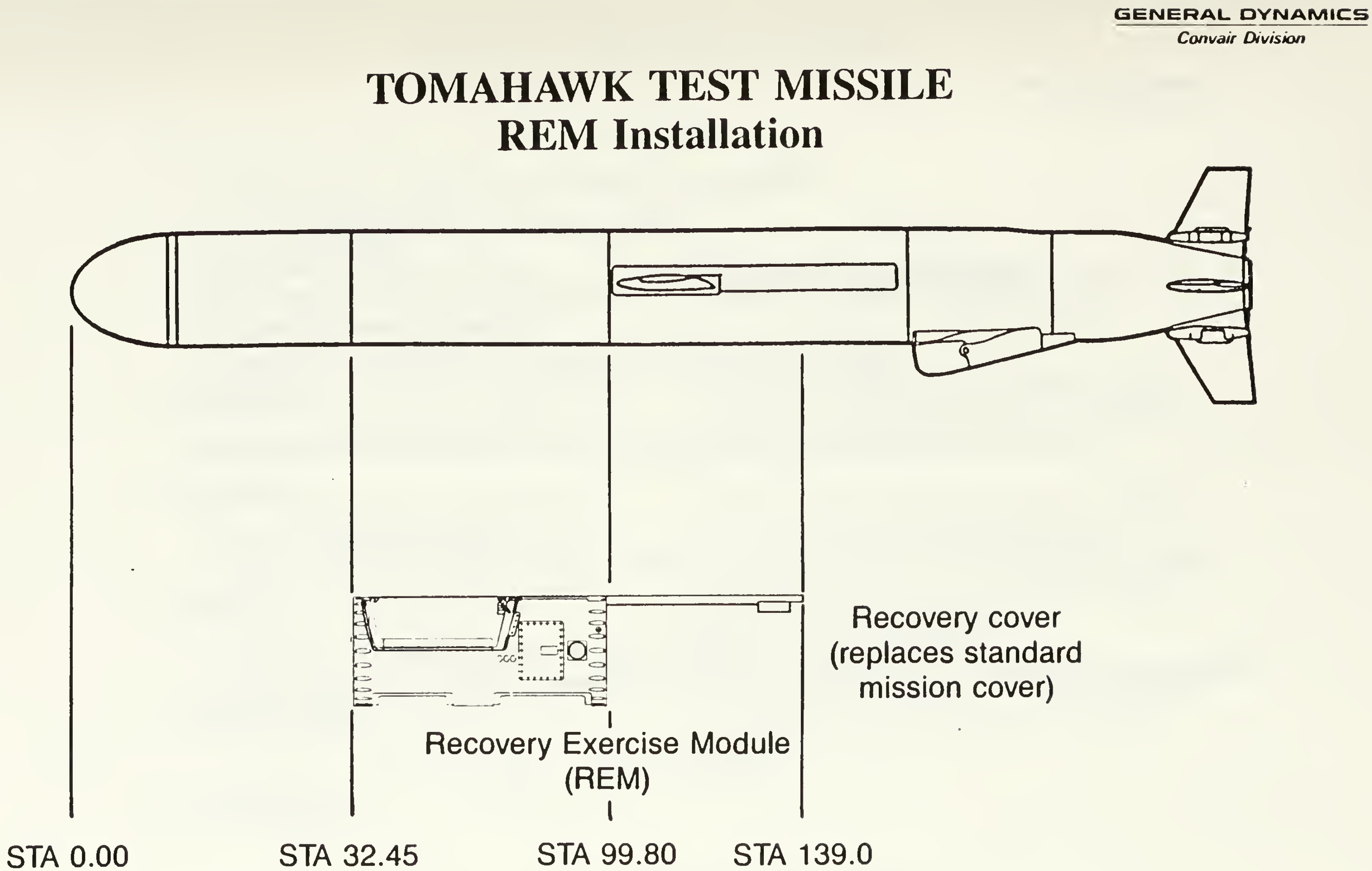
Figure 1. REM Test Failures

D. REM REDESIGN

GD/C is currently the only contractor capable of building/refurbishing the REM. Current goals are to redesign the REM for improved producibility, reliability and maintainability. If approved, the new REM could go into production by late 1988 (Joint Cruise Missile Project, p. 61-64, 1986). The major features, as demonstrated in Figures 2 through 5, also include the ability to refurbish the REM for reuse in less time than the current REM, thus decreasing the need for additional REMs. The new Pulse Code Modulation (PCM) encoder will enhance telemetry data from the missile. The old PCM encoder, used on most current REM models, had experienced a 50% failure rate.

> The FY87 acquisition approach is currently planned as a sole source contract award to GD/C for REM/RSS hardware requirements. The sole source justification is based on the unique development experience of GD/C, the original designer and developer of REMs/RSSs, and the limited number of units procured each year. GD/C and MDAC have been transferring and exchanging technical data as part of a competitive dual source program for the AUR. The REM and RSS kit data package, however, has not been a part of this exchange program. The current data package that has been generated is not adequate for competitive reprocurement data package. Therefore, the government did not buy engineering drawings adequate for competitive reprocurement of REM and RSS kits. Along with the fact that GD/C is the only company having the expertise to manufacture REM and RSS kits, GD/C is also the only company capable of producing them in a timely fashion. (Joint Cruise Missile Project, p.10, 1986)

Drawings and a data package are being procured from GD/C and component subcontractors in order to compete production for the REM and RSS.



(General Dynamics, 1986)

Figure 2. Tomahawk Test Missile With REM Installation

GENERAL DYNAMICS
Convair Division

REM REDESIGN FEATURES

- Producibility
  — Modular subassemblies & cast structure
- Maintainability
  — Design of REM permits ready access for testing, fault detection, repairing & replacing components without demating the missile
- Quality
  — REM conforms to the same quality requirements as the production AUR (QAPP NCM-9585D)
- Reliability
  — REM does not degrade AUR reliability by more than 1%
- Functional
  — Minimizes operational timeline deviation & missile performance degradation
  — Incorporates TLM enhancement & expanded developmental test capability
  — Incorporates enhanced built-in test
  — Incorporates multimissile mission capability

(General Dynamics, 1986)

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Figure 3. REM Redesign Features

GENERAL DYNAMICS
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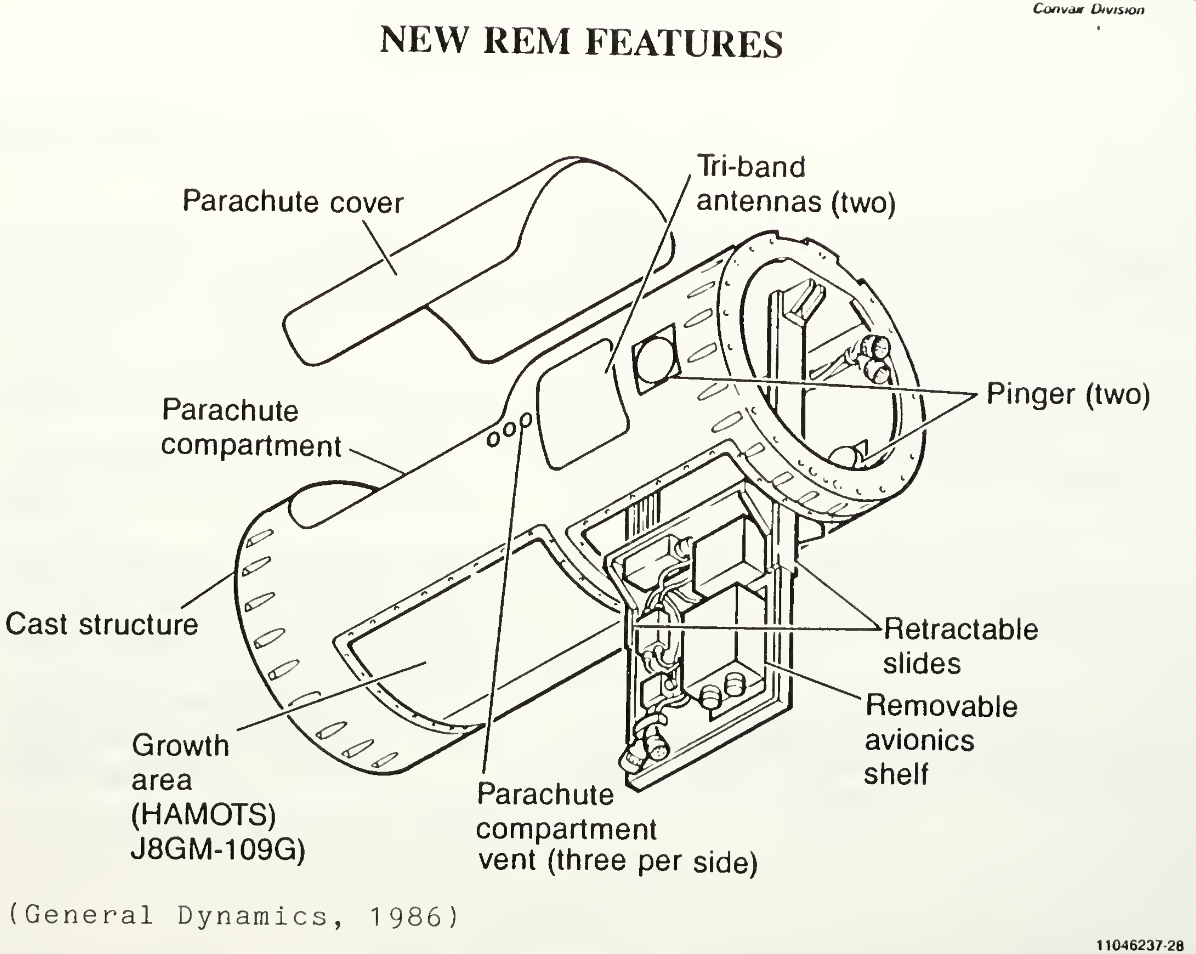
BACKGROUND

	DEFICIENCIES	REDESIGN.
1.	CURRENT REM DISRUPTS MISSILE OPERATIONAL TIME-LINE DUE TO REM BATTERY POWER-UP TIME	REDESIGN REM USES CMA BATTERY AND DOES NOT DISRUPT OPERATIONAL LAUNCH TIME-LINE
2.	CURRENT REM HAS IMPACTED BUILD-UP AND REM/MISSILE CHECK-OUT SCHEDULES DUE TO MAINTAINABILITY DIFFICULTIES	REDESIGN REM PROVIDES READY ACCESS THROUGH RETRACTABLE/REMOVABLE AVIONICS SHELF AND OBVIATES NEED FOR MISSILE DEMATING
3.	CURRENT REM VENTING SYSTEM DOES NOT ALLOW FOR MAXIMUM DEPTH LAUNCHES	REDESIGN REM HAS DESIGN/STRUCTURAL CHANGES FOR POSITIVE DEEP LAUNCH CAPABILITY
4.	CURRENT GFE C-BAND TRANSPONDER IS NO LONGER BEING PRODUCED	REDESIGNED REM/RSS WILL INCORPORATE NEWLY QUALIFIED C-BAND TRANSPONDER
5.	CURRENT TASM RSS IFF TRANSPONDER HAS BEEN DETERMINED TO BE INEFFECTIVE	REDESIGNED TASM RSS WILL USE THE NEW C-BAND TRANSPONDER FOR INCREASED RADAR TRACKING ACCURACY

(General Dynamics, 1986)

Figure 4. Current REM Deficiences and Redesign Corrections

GENERAL DYNAMICS
Convair Division



(General Dynamics, 1986)

Figure 5. Redesigned REM Unit

> The Air Force is currently developing a newly packaged RSS kit called the Non-Tactical Instrumentation Kit (NTIK) for incorporation into the W84 container for in-the-field REM/RSS installation. This new package will allow field replacement of the warhead section with a disposable RSS. This unit will be used for terminal flights only and does not have the capability to recover missiles. This effort will start in FY87 and satisfies the Tactical Air Command requirements for OTL flights. Contract award for the GLCM NTIK will be in early CY87 with the first of 20 NTIKs being delivered in December 1987. (Joint Cruise Missile Project, p.10, 1986)

It should be noted that an RSS is required for OTL flights when the missile is not equipped with a REM. This is to enable the flight to be terminated in the case of uncorrectable problems while the missile is in flight.

E. MISSILE TEST PROCEDURES

The DOD is highly interested in ensuring that the missiles they procure will be operational, if needed. Two factors contribute to operational readiness:

1) Missile system readiness: This includes storage and free flight reliability as well as launch and hit probabilities.
2) Platform readiness: This relates to the ship or submarine and is a function of launch control system availability.

The SLCM TEMP states that:

> anti-ship and land-attack Tomahawk Cruise Missiles are being procured under an AUR warranty concept which includes contractor maintenance for the life cycle of the weapon system. Successful accomplishment of the warranty will be determined in terms of three guarantees: Missile OTL Reliability; Missile

> Recertification/Readiness Reliability; and Missile Turnaround Guarantee. (Conrow, Smith and Barbour: Appendixes, p.41, 1982)

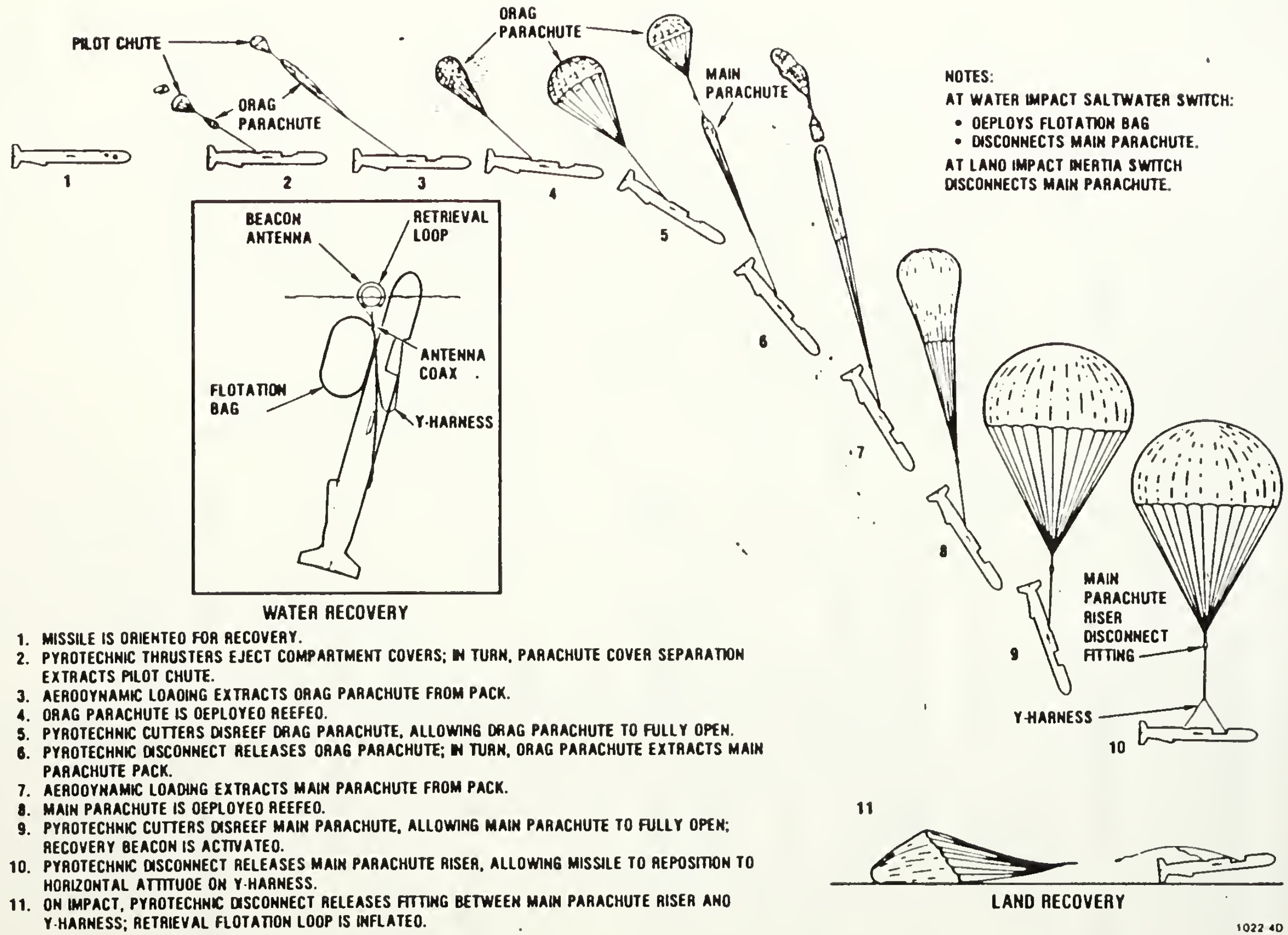
For recertification, missiles are shipped back to the weapons depot for further shipment to GD/C, in San Diego, California or MDAC, in Titusville, Florida. Nuclear warhead missiles are shipped to a depot for warhead removal, prior to shipment to GD/C or MDAC. Recertification cycles are 30 months for TASM missiles and 36 months for TLAM missiles. (Joint Cruise Missile Project, p.72, 1986) In the case of missile recertification the contractor:

> will guarantee that a specified percentage of Tomahawk recertification tests and sample readiness tests on missiles will successfully meet test requirements. The warranty recertification provides planned test maintenance actions which are specifically designed to renew the contractor's confidence in the warrantability of the missile. The readiness test will be performed on a sample basis as selected by the government and extensively exercise the missile in a simulated mission environment test. (Conrow, Smith and Barbour: Appendixes, p.42, 1982)

For the missile turnaround guarantee, the contractor will guarantee that all recertified missiles will be returned to the fleet in a specified time period. (Conrow, Smith and Barbour: Appendixes, p.42, 1982)

The operational test launch procedures are much more complex than that of missile recertification. Just as in the recertification procedures the missiles are sent back to GD/C. After the missile is defueled a REM or an RSS is placed into the missile in the same section previously reserved by the payload. If the missile is meant for a destruction test the RSS will be installed. If the missile is meant to be recovered a REM and REM peculiar kit will be installed. The missile is then refueled and transferred to a weapons station for further transfer to a fleet unit. The missile test which occurs from an at sea unit is usually scheduled to destruct or set down on a land target. Flotation gear is installed in the REM if the missile should land in the water. Figure 6 is an illustration of a land/ sea touchdown.

After an RSS missile test, salvage crews will pick-up any remaining pieces and box them. After a REM missile test, salvage crews decontaminate and crate the missile for shipment back to GD/C. The shipment can be by land or air carrier, however, special precautions must be taken regarding the classified nature of the missiles. Upon return to GD/C the used REM is removed and refurbished for future use on another test missile. The missile is also refurbished and either a new/refurbished REM is installed for additional testing or the missile is returned to a condition for operational use. If the missile is a TLAM-A its warhead is replaced at a designated depot. The missile, once completed, is shipped back to the weapons station for further transfer to a fleet unit.



(Navy SW850-D9-PRO-010/REM MSL Recovery, 1986)

Figure 6. Typical REM-Equipped TOMAHAWK Recovery

III. COST ANALYSIS

A. COST REVIEW

The costs involved in installing a REM for OTLs versus modifying a missile with an RSS will be the subject of this chapter. Costs involved in installing a REM in a missile vary, but are not limited to costs such as purchasing the REM, labor charges for installation, government personnel costs for those dedicated to the project, and transportation costs of shipping a recovered missile. There are costs that are unavoidable, no matter what method of testing is used. These costs include the use of a shipping container and the use of a container used in firing the missile. These containers are usually refurbished for future use but the use of the container will not change with the philosophy of how a test should be conducted. Another example of an unavoidable cost would be the cost of facilities used in the missile testing program. Sunk costs will also be a factor in evaluating alternatives. Sunk costs in this study would include items currently in inventory, such as a REM that has been purchased by the Government.

Project costs can not always be definitive. Costs involved in each missile can easily change with the location of the missile test, the type of damage experienced from a missile landing, part failures, or funding delays.

Therefore, average costs have been used in determining some costs while other costs have been applied by using the best application that is possible in establishing these cost figures. For example, the total number of personnel working on the project may not be known, but a reasonable assumption can be made as to the minimum number of personnel assigned.

The following costs will be evaluated:

AUR missile costs
Current and redesigned REM unit costs
REM installation and refurbishment costs
AUR refurbishment costs
GFP recertification costs for the AUR missile
AUR missile and REM over and above refurbishment costs
Transportation costs for missile shipments
Salvage costs during missile recovery
Recertification costs of an AUR missile
Personnel costs of those involved in the REM project
Nuclear warhead removal costs
RSS unit and installation costs
Costs of missile recovery equipment
Costs associated with the NTIK

B. MISSILE COSTS

The AUR missile costs vary with the different missile variations. This is a factor of economies of scale in the production process and various complexities involved in producing a missile. These include the more sophisticated guidance sets required in the TASM to the increased costs of compensating for a larger payload section in a conventional warhead versus using a nuclear warhead. Costs of missiles that will not be considered are the non-recurring procurement support costs and fleet support costs as these costs will not change with the additional purchase of a missile. Due to the relatively small number of missiles tested in relation to any production population it is projected that purchases of additional missiles to compensate for destruction tests instead of recovery tests will not change the economies of scale for procurement purposes. The number of SLCM test flights that are funded and approved are included in Figure 7.

The cost of the SLCM variants in 1987 dollars during 1987 from the JCMPO POM 88 report are as follows:

COMPONENT FLYAWAY COST	UNIT COST (THOUSAND $) TLAM-A	TASM	TLAM-C
AUR	826	1,209	826
BOOSTER	93	93	93
PAYLOAD		20	20
ENGINE	222	222	222
FUEL		8	
CMRA	28	28	28
DSMAC			355
RMUC	253		253
TOTAL	1,430	1,580	1,806

The fuel is required for product acceptance testing on the TASM. The RMUC is the heart of the guidance set on land attack missiles and is not required on the TASM. The DSMAC is used on conventional land attack missiles, such as the TLAM-C and the TLAM-D.

The total cost figure for a missile during FY88 through FY93 does in fact decrease from as little as $39,000 to as much as $124,000 depending upon the variant, using 1987 dollars. This is illustrated by the cost of a TLAM-C which in FY87 will cost $1,806,000 per missile, but in FY93 (JCM-

SLCM OTL PROGRAM

APPROVED PROGRAM

	PRIOR	FY86	FY87	FY88	FY89	FY90	FY91
TLAM-C/D	0	0	3	5	7	8	8
TLAM-N	3	7	8	8	8	8	8
TASM	7	7	7	7	7	7	7
TOTAL	10	14	18	20	22	23	23
SUB/SHIP	7/3	7/7	10/8	10/10	11/11	11/12	12/11

FUNDED PROGRAM

SUB	7	4	10	6	6	7	10
SHIP	3	7	8	10	11	12	11
TOTAL	10	11	18	16	17	19	21

(Cruise Missile Project Report, 1986)

Figure 7. Funded SLCM Tests

212 Budget Report, 1987) the cost is projected to decrease to $1,682,000. Of course, economies of scale and start-up costs play a major role in the savings.

C. REM COSTS

There are several facets to the cost of the REM. There are the costs of buying the unit from GD/C, the production costs of improving the REM, and the number of times the REM can be utilized on different OTLs.

The cost of the REM in current use, as illustrated in Figure 8, range from $714K to $784K. There are currently 24 REMs that have not been modified with the currently funded production upgrades (funded at $5.8M) and 5 REMs with production modifications (including an upgraded PCM encoder). There are 5 additional REMs scheduled for delivery in FY88. As these items have already been contracted for or are already in inventory the costs will be considered sunk costs. If the decision is made to purchase REMs of similar design an average cost of $748K will be used. The projected cost of purchasing a redesigned REM will be in the range of $444K to $515K depending on the mission peculiar kit required. An average cost of $470K will be used in this study. (General Dynamics, 1986)

The production costs used to accomplish the redesign of the REM include development costs, transition to production (TTP) costs and development of TTP as illustrated in Figures

UNIT COST COMPARISON
CURRENT REM
VS
REDESIGNED REM
(FY86)

CURRENT REM		REDESIGNED REM	
REM UNIT	624K	REM UNIT	441K
EXPENDABLE KIT	85K		
MISSION PECULIAR KIT	3 TO 74K	MISSION PECULIAR KIT	3 TO 74K
	712 TO 783K		444 TO 515K
GFP	2K		
	714 TO 784K		

COST SAVINGS OF $270K PER REM

(General Dynamics, 1986)

Figure 8. Current REM vs Redesigned REM cost Comparison

9 and 10. These costs will be nonrecurring after the initial funding for the project, which is estimated to be $21.4M, as of the 30 March 1987 REM program status report. Of this amount $5.8M has been funded and is considered sunk cost. Therefore, the viable cost to be considered is the $15.6M that remains unfunded. Of this amount $1.6M is for a GLCM commitment, as illustrated in Figure 11. For this study the $14M cost is divided over a five year payback period and 18 OTLs per year. This amounts to an additional cost of $155,556 per flight. It should be noted that if a shorter payback period is considered the cost per flight increases.

The cost of a REM can be broken down into a cost per OTL. From the period of October 1983 through August 1986, seven REMs were rendered unusable during the course of thirty-nine REM installed OTLs, for an attrition rate of 18%. This allows each REM to be used an average of 5.55 times during an average life cycle (this is determined by dividing the attrition rate of 18% into a possible 100% success rate). It should be noted, that in interviews with personnel from the CMPO and GD/C, the original projection was that the REM could be used a total of four times unless it was disabled in an unsuccessful test flight. To date, none of the current REMs in use have been used more than four times. However, all personnel interviewed from the CMPO and GD/C concluded that there is no design deficiency

REDESIGNED REM NON-RECURRING COST

DEVELOPMENT - CDR	
ENGINEERING DESIGN	
DEVELOPMENT HARDWARE FABRICATION	
DEVELOPMENT HARDWARE TESTING	
DEVELOPMENT COST	\$5.8M
TRANSITION TO PRODUCTION (TTP)	
CONFIGURATION MANAGEMENT	
INSTALLATION ENGINEERING	
TOOLING/PLANNING	
VENDOR	
ILS	
EMV/RANGE COMPATIBILITY TEST	
SECTION/COMPATIBILITY TESTING	
QUALIFIED REM	
ONE (1) FIRST ARTICLE REM	
TTP COST	\$15.1M
TOTAL NON-RECURRING COST	\$20.9M

(Cruise Missile Project Report, 1986)

Figure 9. Redesigned REM TTP and Development costs

REDESIGNED TASM RSS NON-RECURRING COST

DEVELOPMENT/TTP

ENGINEERING DESIGN

INSTALLATION ENGINEERING

PLANNING

TOTAL NON-RECURRING COST	$ 0.5M
TOTAL PROGRAM NON-RECURRING COST	$20.9M $21.4M - 5.8M $15.6M

(Cruise Missile Project Report, 1986)

Figure 10. Redesigned REM Non-Recurring Costs

FUNDING REQUIRED FOR REM DEVELOPMENT

TTP	$15.1M
RSS	.5M
TOTAL	$15.6M
GLCM COMMITTMENT	$1.6M
FY85	$1.0M
	$2.6M
TOTAL UNFUNDED REQUIREMENT	$15.6M - 2.6M 13.0m

(Cruise Missile Project Report, 1986)

Figure 11. Redesigned REM Funding Requirements

that would prevent a REM from being used until it is lost through attrition. The per flight cost of a REM installed in an OTL missile is as follows:

CURRENT REM	REDESIGNED REM
$748K / 5.55 =	$470K / 5.55 =
$134,775	$84,685

D. REM REFURBISHMENT/INSTALLATION COSTS

Costs involved in REM refurbishment/installation include the cost of labor to put a used REM back into reuseable condition, cost of GFP, cost to recertify various pieces of equipment contained in the REM, and cost to install the REM in an AUR.

Under the contract of 16 July 1986 REM installations cost $265,347 per installation. Under the contract of 26 November 1986, material and services necessary to install REMs into an OTL missile has escalated to a unit cost of $306,773.

> An AUR to be utilized in an OTL and recovered shall have a REM installed prior to flight. The government furnished REM shall consist of recovery systems, data/telemetry systems, and range safety equipment suitable for the test range to be utilized. Prior to installation in the air vehicle, the REM shall undergo testing and inspection. (JCM-1963, p.24, 1985)

In accordance with the 26 November 1986 contract, materials and services necessary to refurbish the REM, after an OTL, has a unit cost of $48,007. This cost is not included in the cost to purchase or install the REM. It does, however, provide for labor costs necessary to bring the REM back to reuseable condition. Unexpected damage to the REM is not covered in this cost figure, these costs will be addressed in the section dealing with over and above costs. The material costs do not include recertification of GFP or replacement of the REM expendable kit or a mission peculiar kit.

As illustrated in Figure 12, the GFP for the REM expendable kit consists of over 50 separate parts which cost $75,823 (this cost is in 1984 dollars). The REM mission peculiar kit for a SLCM depends on the missile variant used. The mission peculiar kit for a TLAM-A (R/UGM-109A) costs $50,247 while the mission peculiar kit for a TASM (R/UGM-109B) costs $31,478. The government equipment provided in a REM consists of the RCUR/Decoder (part number 76A0394-5). The unit is recertified at the Pacific Missile Test Center (PMTC), Pt. Magu, California. The cost to accomplish this is $877 not including transportation costs, which are considered minimal, for this study.

Contract No: N00032-84-C-4484
Control No: CM81-618-06

ITEM	SUPPLIES OR SERVICES	QTY	UNIT PRICE	TOTAL PRICE
0027	REM Expendable (REM-X) Kit for R/UGM-109A, B, C (USN) (EID: 76-410)	13	$75,823	$985,699
0028	REM Expendable (REM-X) Kit for BGM-109G (USAF) (EID:76-410)	7	$75,823	$530,761

Figure 12. Excerpt From 19 December 1984 Contract REM-X Kit

E. AUR REFURBISHMENT AND MISSILE GFP RECERTIFICATION

> Refurbishment consists of those maintenance actions required to rebuild recovered test flight AURs. Components and body sections may be damaged during test flight and subsequent recovery activities. Refurbishment shall include disassembly; decontamination; removal of parts and assemblies for test, repair, or replacement of expended items, reassembly and retest. The refurbishment AUR is delivered as a fully recertified missile. (JCM-1963, p.44, 1985)

Under the contracts illustrated in Figure 13 the average cost for basic supplies and labor services to refurbish an AUR, after an OTL, is $247,307 for missiles that were tested between December 1985 (T-265) and August 1986 (T-311). Under the 26 November contract, material and services necessary to decontaminate recovered flight test missiles and remove the SLCM REM is $33,078 per missile.

Contract No: N00032-86-C-6113
Control No: N00032-86-PR-60730.03

ITEM	SUPPLIES OR SERVICES	QTY	UNIT PRICE	TOTAL PRICE
0106	AUR Refurbishment RGM-109A-1 (T-258, T-262, T-311)	3	$243,159	$729,477
0107	AUR Refurbishment UGM-109A-1 (T-265)	1	$249,158	$249,158
0110	AUR Refurbishment UGM-109C-1 (T-180)	1	$245,795	$245,795

Control No. CM81-658-06

ITEM	QTY	TASK	TOTAL FIRM FIXED PRICE
0110	1	Refurbishment of T-180	$257,902

(This represents a modification to Control No: N00032-86-PR-60730.03)

Figure 13. Excerpts From Contract No: N00032-86-C-6113 With Modification of 28Feb86; AUR Refurbishment

There is an extensive number of parts that are provided to GD/C by the Government to properly complete the AUR refurbishment. There are over 75 parts provided at a cost of $335,165. Additionally, a new rocket motor must be provided. The components for the motor cost $90,000 while the assembly of the components adds $40,000 to the cost. These costs do not count any parts that are damaged beyond the normally expected items.

Part of the costs of bringing the missile up to requirements includes the recertification of various GFPs. These include the RMUC (sent to Litton Industries), the CMRA (sent to Honeywell), the DSMAC (sent to the Naval Avionics Center), and the engine (sent to WIC). The costs included in the recertification process amount to $83,000.

F. AUR/REM OVER AND ABOVE REFURBISHMENT COSTS

When a fixed firm price contract is used for repair of equipment, that has some unknown damage possibilities, there are usually additional repair costs. Costs can occur while preparing the missile for its OTL or during refurbishment after the OTL.

> Unscheduled maintenance can consist of two (2) types of requirements: unscheduled maintenance and unplanned rework maintenance. The former refers to maintenance required on missiles returned from government inventory for other than scheduled maintenance action. Repairs to be accomplished will be determined from missile records, diagnostic inspections, and tests at the depot(s). The scenario for unscheduled missile maintenance is logically varied due to the unknown causes initiating such maintenance. This unscheduled maintenance will

therefore be accomplished by the depot(s) to the extent necessary to return of the AUR to an operationally ready condition. (JCM-1963, p.45, 1985)

With a REM flight, excess damage can occur from a hard landing or from hitting large rocks or trees during landing. Excess damage can be in the form of structural damage to the missile or damage to missile/REM parts. Although not all missiles or REMs incur costs that are not covered in the basic refurbishment or recertification contracts (over and above costs), most do require some additional work. The over and above costs have had variations as great as $100K. For example under contract N00032-86-G-3009, T-926 experienced costs of $3,844 while T-314 experienced costs of $108,554.

Over and above costs may not be funded in the same year refurbishment costs are funded and funding may be applied to different contracts. Therefore, a definitive average of over and above costs is impractical to discern, from this study¢s standpoint. Accordingly, the average cost generated by CMPO of $48,000 will be used.

G. TRANSPORTATION COSTS

Shipments of classified material require that special security precautions be taken. This includes dual driver protective service, protective security service, exclusive use of the vehicle, and telephone notification of shipment location and status en route.(JCMPINST 4601.1A, p.1-2, 1985)

The cost of initially shipping a missile selected for an OTL to GD/C from a weapons station or shipping a missile to the launch center is considered only in the framework that if the NTIK system were adopted it would be applicable. For simplicity a missile shipment from Naval Weapons Station, Seal Beach, Ca. and a return shipment to the Utah Test and Training Range (UTTR) is considered. From information provided by the CMPO the approximate cost to ship a missile from Seal Beach is $2,100 while the cost to UTTR is approximately $8,200.

After an OTL, only missile fragments from the destroyed missile that are scattered about the destruction area require shipment. However, a REM equipped OTL must be shipped back to GD/C for refurbishment. This could be from any test area. However, in most cases it will be from the UTTR, San Clemente Island, Naval Weapons Center, China Lake, Ca, or Tonopah Test Range, Nevada. Other test areas may be off Puerto Rico or the Aleutian Islands. After refurbishment the missile is then shipped back to its destination, which could be Yorktown, Va., Norfolk, Va., Groton, Conn., Concord, Ca., Pearl Harbor, Hawaii, or Guam. Again using UTTR the cost to ship a single missile to GD/C is approximately $8200. As an average the cost to ship a missile to the East Coast is used. Therefore, the cost to ship a missile from GD/C to Norfolk, Va., as provided by the Military Traffic Management Command, Western Area, is $3954 per vehicle load (1.30 per vehicle mile plus .20 per mile for dual drive service time; 2636 miles) or approximately $2000 if two missiles (which is a more realistic number of missiles that would be shipped together on one vehicle) are shipped.

H. SALVAGE COSTS

Missile can be launched from land, sea, or air. In the case of the SLCM, most launches are from sea units. However, almost all test launches are destined to touchdown over land. The REM is equipped with a flotation device if the missile does go into the water, accidentally. Unfortunately, the damage to the missile from the salt water can be extensive.

After a land touchdown, the test range ensures the missile is safe, in relation to any unexpended portion of payload. It then prepares the missile for shipment back to GD/C. The costs of a REM missile recovery is as follows:

RECOVERY AREA	COST
UTTR	$23,241
Tonopah Test Range, Nevada	22,028
Naval Weapons Center, China Lake	22,252
San Clemente Island	15,698

For purposes of this study an average cost of the four recovery areas ($20,805) will be used.

I. RECERTIFICATION COSTS

Although recertification costs do not directly affect the cost to refurbish a missile, their costs do affect the overall analysis. If a TLAM is stored for 36 months it must be sent back to GD/C for recertification. However, if that same missile is used in an OTL its recertification clock starts all over after refurbishment and the cost to recertify the missile does not occur. The general assumption is that a missile will be pulled from inventory half way through its recertification time clock and be used, for testing purposes. The average cost of a recertification generated by the CMPO is $202,000. This cost includes the contractors labor to recertify the missile, GFP, and any unscheduled maintenance. Using this figure, a cost avoidance of $101,000 (half the recertification time that is saved times the $202,000) is realized. However, this cost avoidance will be realized only if the REM utilized OTLs continue and refurbishment of the missile satisfies the recertification requirements.

J. PERSONNEL COSTS

A program of the magnitude of the REM project has significant costs associated with personnel hired to work full time on the program. There are also employees that work part time on this program . Without extensive research it is difficult to determine the exact number that do work on the REM program. At the JCMPO headquarters in Washington D.C. there are at least two individuals that work exclusively on REM analysis and policy. At DCAS GD/C there is one individual dedicated to the program; however, there are several others that work nonexclusively on the REM program. They may establish proper over and above costs by the contractor, maintain track of government missiles being refurbished, or provide contract services. These part time services, in themselves, more than make up the work of one full time individual. At the test ranges there are many individuals that work on missile recovery teams. If the missiles were destroyed versus recovered the numbers could easily be reduced. An FY88 proposal by the Naval Weapons Center, China Lake (currently designated as the technical direction agent for the REM redesign) indicates a need for 8.6 man-years to work on the REM redesign at a cost of $1.428M. Since the redesigned REM program will take at least two years, it is presumed, similar funds will be required over the next two years. Some of the tasks to be accomplished with these personnel include:

- Technical design support
- Support of competitive bid/proposal evaluation
- Monitor development of the new REM
- Monitor and evaluate design performance tests
- Monitor and evaluate qualifications tests
- Monitor and evaluate integration/interface tests
- Review and approval of all test plans
- Review design analysis
- Manage configuration and data management
- Review all drawings to ensure compliance with MILSTNDs
- Maintain master data package

Costs of personnel at CMPO and DCAS will be listed by Government Service (GS) rating. Salaries for each pay level will be taken at step 5. Fringe benefits include 20.4% for retirement benefits, 3.7% for insurance benefits, and 1.9% for federal workers compensation, bonuses, etc. The following is a breakdown of the minimum estimated cost (Department of Defense Instruction 4100.33H, 1980) of personnel that work on the REM program:

RATING	YEARLY SALARY	FRINGE BENEFITS	TOTAL COST
GS-13	$ 43,891	$11,412	$ 55,303
GS-12	36,911	9,597	46,508
GS-9	25,454	6,618	32,072
GS-9	25,454	6,618	32,072
TOTAL	$131,710	$34,245	$165,955

Taking the total personnel costs, of $1,593,955 ($1.428M plus $165,955), and dividing it by an average of 18 funded test flights per year, over the next four fiscal years, gives an additional cost per test launch of $88,553.

K. NUCLEAR WARHEAD REMOVAL COSTS

When a TLAM-A is tested the nuclear warhead must be removed and replaced with a unit that simulates the weight distribution of this unit. The unit is a W80 JTA/NTA. Removal of this unit under the contract of 26 November 1986 costs $3,776 per removal.

L. RSS UNIT AND INSTALLATION COSTS

If an OTL missile is not to be recovered the test missile must have a government furnished RSS installed which meets the requirements of the range over which the missile will be flight tested. The procedure is that a selected AUR is shipped to the depot where a RSS package is installed. The missile is then transferred back to the fleet for testing. (JCM-1963, p. 24 - 44, 1985)

A test flight not configured with the REM must therefore have a safety system installed. The RSS is the device currently used by the CMP. Costs that are associated with this system, that are relevant to this study, are the costs of purchasing the RSS and the materials and services (including labor) necessary to install the RSS into the OTL missile.

Under the contract of 26 November 1986 item 0211, the cost to install the RSS is $215,069. The cost to fabricate and assemble a RSS, under a 1986 Form 1411, is an average cost of $235,305 for the BGM-109B and the BGM-109C models.

M. COSTS OF MISSILE RECOVERY EQUIPMENT

Each fiscal year a portion of the SLCM budget is dedicated for the expenditure of fleet support costs. These costs include support equipment, training equipment, documentation, and Theater Mission Planning Center (TMPC) equipment. For FY87 the cost was approximately $61M and in FY88 the budget calls for expenditures of over $73M. A portion of these costs do go to the support of missile test flights. This may include documentation or training on missile recovery or tools to ensure a missile is properly prepared for shipment after recovery. Costs for the REM project, however, are not discernible from the remainder of the support costs for the entire missile project and this study does not attempt a breakdown. However, it should be kept in mind that there is a cost to the REM project.

N. COSTS ASSOCIATED WITH THE NTIK

When the NTIK is installed at the overseas depots:

> a certified load crew will decanister the missile and demate the W84 warhead. The NTIK will then be installed using technical order procedures. This will include connecting the W1 wiring harness. Test-unique functions such as W2 harness, antenna coaxial connection, and nose cone installation will be accomplished using additional formal published technical data procedures. The recanistered AUR will be uploaded and Bit accomplished. Upon receipt of successful Bit, the AUR will be downloaded and placed in a standard shipping container for transport to the CONUS for flight test. Great care will be taken to ensure accountability of AUR components during packing. The AUR will be flown to the designated launch site support airfield, then transported to the launch site. (Concept of GLCM Flight Evaluation Operations and Logistics, p.2, 1986)

Figures 14 and 15 depict the NTIK system design.

The unit cost of the GLCM NTIK is $350K per unit. The pre-flight costs per unit (includes reassembly of the missile, pre-flight testing and calibration, and packaging for shipment) costs $3.2K. (Hill and Myers, p.4-6, 1986)

When utilizing the NTIK in an OTL the test flight can be conducted for the maximum time that a non-test missile could be flown. This is possible because the NTIK does not displace any of the fuel section of the missile, as is the case with the REM. The NTIK OTL can last an one and one-half hours longer than is possible in a REM test flight.

UNCLASSIFIED

GLCM NON-TACTICAL INSTRUMENTATION KIT

GENERAL DYNAMICS
Convair Division

Preliminary Design Review

NTIK SYSTEM CONCEPT

GLCM-NTIK IS A RANGE SAFETY KIT DEVELOPED TO BE USED ON FULL-RANGE BGM-109G TEST FLIGHTS. PRIMARY OBJECTIVES ARE:

- CONFIRM MISSILE READINESS IN THE FIELD BY CONVERTING A TACTICAL MISSILE TO TEST MISSILE IN THE FIELD WITH MINIMUM HARDWARE MODIFICATION

- FLY FULL-RANGE MISSIONS TO DEMONSTRATE ACTUAL MISSILE RANGE & TERMINAL ACCURACY

SPECIAL FEATURES THAT SUPPORT THE ABOVE OBJECTIVES:

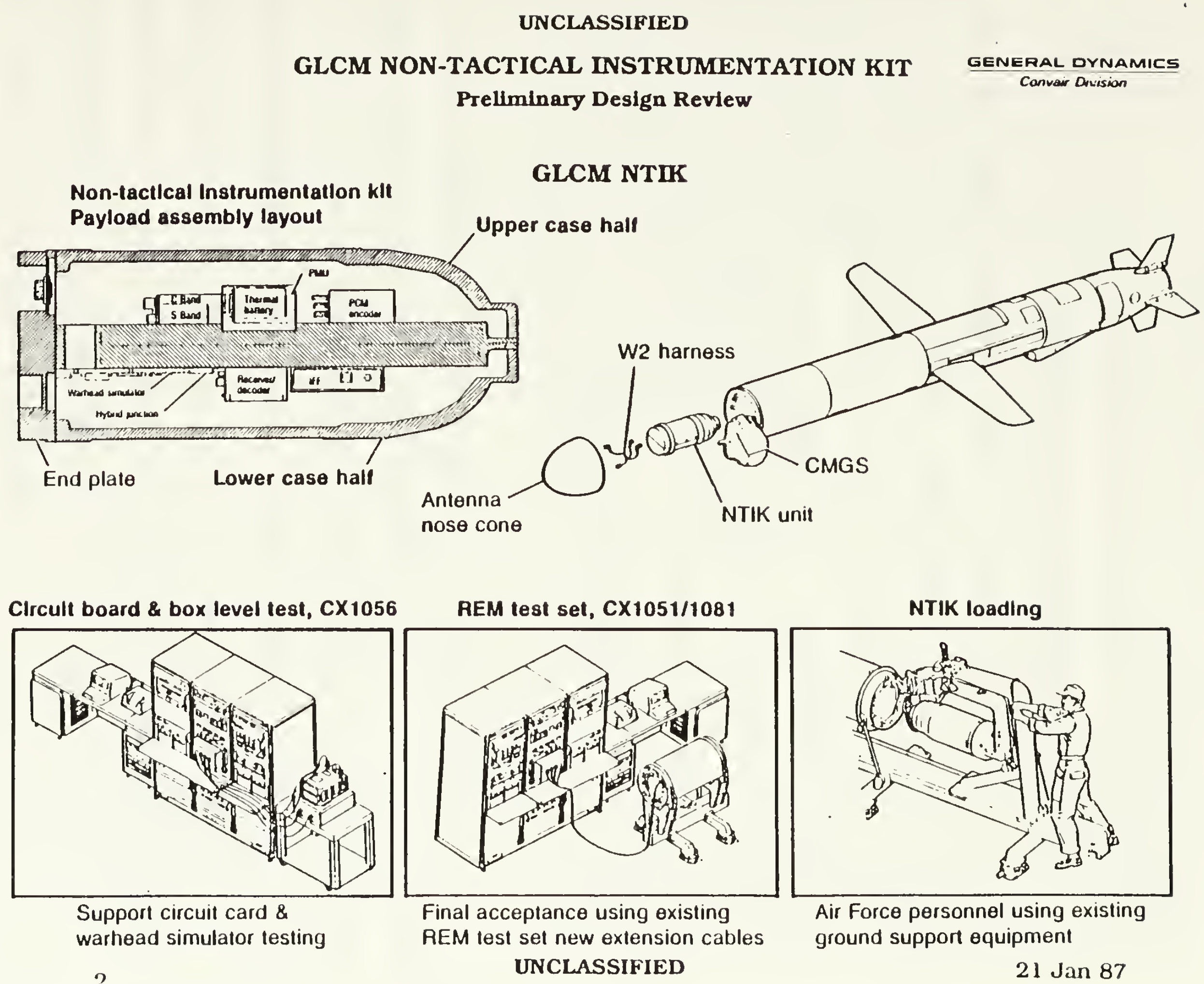
- NTIK IS DESIGNED TO BE DELIVERED DIRECTLY TO & INSTALLED IN THE FIELD BY AIR FORCE PERSONNEL. THE NTIK IS A DIRECT REPLACEMENT FOR THE W84 NUCLEAR WARHEAD AND PRODUCTION NOSECONE.

- NTIK PROVIDES A HIGH-ALTITUDE TRACKING AID SO THAT THE MISSILE CAN BE TRACKED FROM RANGE TO RANGE EVEN IN BAD WEATHER WHEN CHASE PLANES CANNOT BE USED.

(General Dynamics, 1987)

1 UNCLASSIFIED 21 Jan 87

Figure 14. NTIK System Concept



(General Dynamics, 1987)[2]

Figure 15. GLCM NTIK

This increases the costs at the test ranges and aircraft tracking time. The test ranges support costs total an additional $12.5K per hour or $18.75K per OTL. The additional flight costs of an F-4 to track the missile during flight time is $4K per hour or $6K per OTL. (Hill and Myers, p.10, 1986)

Due to the different structure of the SLCM from the GLCM a variation of the NTIK, would have to be developed for each SLCM. The TLAM-A uses a W80 warhead versus the W84 warhead used in the GLCM. The nose cone areas of the TASM and TLAM-C are also different and would require an NTIK of a different variation. No exact costs can be determined for these alternatives without soliciting the contractors for bids. Development costs would be a big factor even if the costs of a SLCM NTIK were similar to the GLCM NTIK.

O. COST ANALYSIS

As indicated, the costs of utilizing a REM vary from those paid to the contractor through firm fixed price contracts to the everyday operating costs of the project office. The major costs, such as the GFP for the missile and the REM installation, are the costs that can be directly associated with the missile refurbishment. Cost factors for personnel or the recertification cost avoidance are more intangible, but they should be included as costs to the program. After all, if the REM program did not exist the number of personnel cited herein could have been utilized elsewhere, or employment vacancies may not have even been generated.

The costs cited in this Chapter are summarized below:

ITEM	COST
Missile Costs	
TLAM-A	$1,430,000
TASM	1,580,000
TLAM-C	1,806,000
REM Unit Cost (per flight; per life cycle)	
Current Model	134,775
Redesigned Model	84,685
REM Refurbishment	48,007
REM Installation	306,773
REM Expendible Kit	75,823
REM GFP Recertification	877
AUR Refurbishment	247,307
AUR GFP Required	335,165
AUR Rocket Motor and assembly	130,000
AUR Parts Recertification	83,000
REM Removal and Decontamination	33,078
Over and Above Costs	48,000
Extra Transporation Costs	10,200
Salvage Costs	20,805
Personnel Costs (per flight; 18 per year)	88,553
Recertification Cost Avoidance	(101,000)
Nuclear Warhead Removal	3,776

When using average figures, such as number of tests flights per year or the number of times a REM can be utilized in a average life cycle, disparities in the figures can easily materialize. Within this study the cost swings should occur in the lower cost items (those under $100K). Thus, the effects of any changes in operational factors on the outcome will be negligible.

IV. ANALYSIS OF ALTERNATIVE SOLUTIONS

A. ALTERNATIVES REVIEW

The analysis contained herein looks at alternative solutions to the procedures under which the REM program could be run. The alternatives described may be either conventional or unconventional in terms of present program philosophy. However, it is always healthy to look at a program that has been in existence as long as the REM program from perspectives not previously considered. This research study has not analyzed the cost of the program in its entirety, nor does it make judgements on the way operational tests should be conducted. Instead, it analyzes the cost of testing an individual missile. All costs relate to the cost information provided in Chapter III. The following alternatives will be discussed in this research study:

Maintain use of the current REM model
Buy a new redesigned REM model
Don't use REMs and destroy all test missiles
Use up in stock REMs, then destroy all test missiles
Convert to use of the NTIK
Compete the production/refurbishment of the REM

B. MAINTAIN USE OF THE CURRENT REM MODEL

Using the current REM model would mean scrapping plans for the development of a new redesigned REM model. One of the reasons given for scrapping the current REM model and converting production to a new REM model was to increase reliability of the unit. However, since 1980 the REM has not been the cause of a single failure of an OTL. Figure 1, in Chapter II describes both of these failures. Using the current REM does mean a missile would have to be demated if problems are discovered after installation. This is in contrast to the convenience of pulling out an electronics shelf as would be possible on the redesigned REM. Benefits of having a new redesigned REM as described by GD/C are illustrated in Figure 16. Continuous use of the current REM would require purchase of additional REMs for use in future years, as illustrated in Figure 17. Therefore, REMs in inventory can not be considered as sunk cost when using this option. There are currently 29 REMs in inventory, with 5 more REMs scheduled for delivery in FY88. Using an 18% attrition rate the current supply will be exhausted in just over 6 years. REM turn aroundtime, from removal after an OTL to ready for use condition, would further shorten the availability of the REM, without replacements.

The cost of an OTL using the current REM model is depicted in Figure 18. At a cost of $1.46M it may not seem cost beneficial to refurbish the test missile in the case of a TLAM-A or a TASM, which cost $1.43M and $1.58M, respectively. This is especially true if one considers that at a projected inflation rate of 3.5% over the next three years the cost of a OTL utilizing a REM will increase to

GENERAL DYNAMICS
Convair Division

OPERATIONAL RECOVERY EXERCISE MODULE (REM) DESIGN REQUIREMENTS

Improve maintainability

- Permit ready access for testing, fault detecting, repairing & replacing components without demating the missile

Improve capability

- Increase REM launch capability to the maximum depth of the production missile

Improve producibility

- Reduce manufacturing problems associated with welded structure assembly

(General Dynamics Report, 1987)

Figure 16. Redesigned REM requirements

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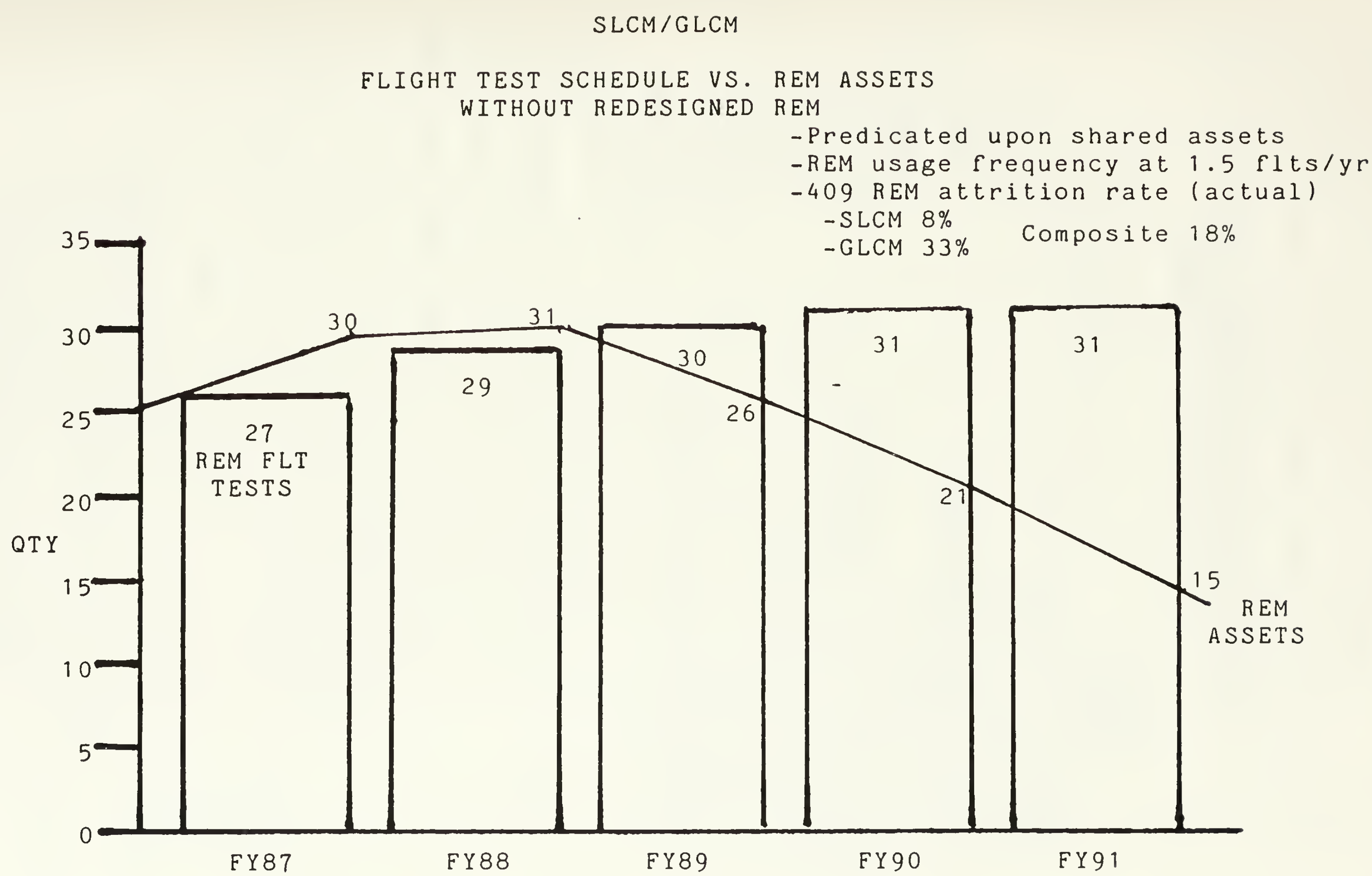

(General Dynamics Report, 1986)

Figure 17. REM Assets

COSTS TO REFURBISH A CRUISE MISSILE
USING THE CURRENT REM MODEL

ITEM	COST
REM Unit Cost (per flight)	$134,775
REM Refurbishment	48,007
REM Installation	306,773
REM Expendible Kit	75,823
REM GFP Recertification	877
AUR Refurbishment	247,307
AUR GFP Required	335,165
AUR Rocket Motor and assembly	130,000
AUR Parts Recertification	83,000
REM Removal and Decontamination	33,078
Over and Above Costs	48,000
Extra Transporation Costs	10,200
Salvage Costs	20,805
Personnel Costs (per flight)	88,553
Recertification Cost Avoidance	(101,000)
Total Cost	$1,461,363

Figure 18. Current REM Costs

$1.66M. However, it must be remembered that if a REM isn't utilized a safety system must be installed. Therefore, the cost to install an RSS must be considered. The relevant costs of an RSS utilized OTL is as follows:

ITEM	COST
RSS Unit Cost	$235,305
RSS Installation Cost	215,069
Total RSS Costs	$450,374

The net cost to utilize a REM in an operational test is $1,010,989 ($1,461,363 minus $450,374) when the RSS requirements are considered. This makes the use of the current REM a viable alternative in all SLCM variants able to effectively accomodate the REM.

C. BUY THE NEW REDESIGNED REM

To buy the new REM will mean funding the necessary transition to production (TTP) costs. It will, alternatively, decrease the costs of REM utilized OTL as the unit cost of the new REM is less then the cost of building the current REM model. This factor will be more significant five to ten years into the program as the TTP costs are no longer a factor. The costs will be similar to the cost of using the current REM with the following exceptions:

ITEM (Per Flight)	COST
Redesigned REM Cost	$ 84,685
REM TTP Costs	155,556
Additional Personnel Costs Costs for NWC, China Lake ($1.428M)	79,333
Current REM Cost	(134,775)
Total Additional Cost; New REM	$184,799

Using a present value (PV) analysis of the project, with a cost of capital of 10% over the next 15 years the following costs are provided (REM unit savings is equal to the cost per flight of the current REM, of $134,775, minus the cost per flight of the redesigned REM, of $84,685, times 18 test flights per year):

ITEM	COST/ SAVINGS	NO. YEARS	PV FACTOR	TOTAL
TTP Costs	$14,000,000	1	1.000	$14,000,000
Personnel Costs	1,428,000	2	1.7355	2,478,294
REM Unit Savings	901,620	15	7.6061	(6,857,812)
PV Cost Of Using The New REM				$ 9,620,482

Considering the high cost for TTP and the additional personnel costs the purchase of a new redesigned REM can not be justified from strictly a cost standpoint.

D. USE THE RSS ON ALL FUTURE TEST FLIGHTS

As previously specified, if a missile does not utilize the REM a safety system must be installed. The RSS is the safety system in current use. Therefore, no matter whether the REM or RSS is utilized there is a cost. For the REM it is the $1.46M to refurbish the missile, and for the RSS it is $450K for unit and installation costs plus the cost of a new missile (costs vary from $1.4M for a TLAM-A to $1.8M for a TLAM-C). Unless the cost of utilizing a REM increase 33% faster than the cost of an RSS and a new missile the REM should be used on future OTLs.

E. USE REMs IN STOCK THEN USE THE RSS

With 34 REMs in stock, after delivery of 5 new REMs in FY88 and an 18% attrition rate the REMs in stock should last approximately 6 years. Since the REMs in stock are sunk costs the real cost to redo a REM missile is as follows:

ITEM	COST
Current REM Refurbishment Cost	$1,497,270
Current REM Unit Costs (per flight)	134,775
Updated REM Refurbishment Cost	$1,362,495

However, this temporary cost savings of $134,775 over 18 test flights for 6 years cannot offset the costs of purchasing new missiles, at an average cost of $1.8M, in the later years of the program. Therefore, this is not a viable option.

F. CONVERT TO USE OF THE NTIK

The NTIK is an alternate system to the RSS. To utilize this system the Navy would be required to spend millions of dollars in development and TTP costs. The savings in utilizing the NTIK over the RSS would be only in the reduction of installation costs. There are SLCM variants that are tested with an RSS, therefore, a cost analysis of the use of the NTIK and the RSS can be made. Cost projections through the defense contractors will have to be made in order to present an accurate analysis of the situation. But, in the overall analysis it does not appear beneficial to use the NTIK in place of the REM for the same reasons it is not beneficial to use the RSS in place of the REM.

G. COMPETE THE PRODUCTION OF THE REM

As illustrated in this research study, determining the true costs of utilizing the REM has been difficult. Current contracting procedures have corrected some of the problems (i.e. REM costs are broken down into separate items in the contract versus being grouped into the overall missile costs). However, tracking the spiraling costs of the REM program is impractical, due in part to the above circumstances, although the costs have appeared to be increasing at a pace well above the current rate of inflation. For example, the average cost of a REM and Mission Peculiar Kit in Contract number N00032-83-C-3329 of 23 May 1983 was $416,620. In 1987 the average cost was $748K. This represents an average cost increase of almost 16% per year over the last four years. The cost to refurbish a REM in the contract of 23 May 1983 was $32,153 versus a cost of $48,007 in 1987. This represents an increase of over 10% per year.

At these rates it may be cost effective to use the RSS in test flights in a matter of years. These increases can be attributed, at least in part, to the use of a single source contractor. If these costs were in line with the real inflation rates, during the past four years the cost increases should have been approximately 6% per year. Additional considerations of learning curve factors and economies of scale should have also meant a decrease in costs.

Competition for this multi-million dollar program will in all likelihood reverse the cost trends of the past. It may, in fact, make production of a new redesigned REM cost effective. However, this alternative requires more detailed analysis.

H. POLITICAL CONSIDERATIONS

Current negotiations with the Soviet Union call for vast decreases in nuclear weapons in Europe. If negotiations are fruitful, the United States may have an excess of GLCMs. Due to the modular design of the Cruise Missile GLCMs can be converted to SLCMs. However, this may produce an inventory of SLCMs that is far in excess of those needed to practically defend this country. With this in mind, it would then be beneficial to utilize a RSS or NTIK in OTLs of the Cruise Missile. The relevant costs in this situation would be the $450K to use a RSS versus a cost of $1.46M to utilize a REM.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In a project the size of the REM program change occurs gradually over the course of time. In the case of the REM the program has continually expanded from its conception in the late 1970's. During the present time decisions are being made as to the cost effectiveness of building a new REM. From the data presented in this research study, at the present time it is cost effective to utilize the REM for OTLs. The question becomes, what direction should the REM program take over the next several years?

The most effective direction appears to be utilization of the current REM and scrapping the plans to build a new redesigned REM. This is mainly due to the high costs of TTP and extra personnel costs. However, part of the problem may center around the single source strategy used by the CMPO. If the redesigned REM along with refurbishment was competed between defense contractors, such as GD/C and MDAC, the cost might certainly decrease over the long run. At least the high inflationary trends that currently exist in the program may cease.

Considering cost factors while excluding technical factors, the TTP costs will have to decrease by over $8M for the redesigned REM to be cost effective. A decrease in the cost of the redesigned REM will also offset the costs for TTP. It should be remembered that 18 REM flights were used as a utilization factor. If fewer flight are planned or a shorter payback period on the program is sought the cost per flight will increase, since $14M is a high fixed cost. The TTP costs may also be too high a cost to spend in relation to current budget constraints.

The use of the NTIK should be evaluated against the use of the RSS. To do this a preliminary evaluation can be made with GD/C (current contractor for the GLCM NTIK) as to feasibility and cost effectiveness.

B. RECOMMENDATIONS

The overall recommendation is to continue to use the current REM. This includes purchase of the current REM model to meet outyear requirements. However, competition should be investigated for this program. Unfortunately, the size of the program may not allow the same type of dual sourcing that missile procurement experiences.

If substantial reductions can be made in the cost of the new redesigned REM the transition should then be made. Finally, to maintain cost effectiveness of the program, one division of the program office should be given the collateral task of keeping track of all REM associated costs.

APPENDIX

ABBREVIATIONS AND ACRONYMS

ABL	Armored Box Launcher
ALCM	Air Launched Cruise Missile
AUR	All-Up Round
BAC	Boeing Aircraft Company
CMPO	Cruise Missiles Project Office
DOD	Department of Defense
DSARC	Defense System Acquisition Review Council
DSMAC	Digital Scene Matching Area Correlator
GD/C	General Dynamics Convair Division
GFE	Government Furnished Equipment
GFP	Government Furnished Property
GLCM	Ground Launched Cruise Missile
JCMPO	Joint Cruise Missiles Project Office
K	Thousand
M	Million
MDAC	McDonnell Douglas Astronautics Company
NM	Nautical Miles
NTIK	Non-Tactical Instrumentation Kit
OSD	Office of the Secretary of Defense
OTL	Operational Test Launch
PCM	Pulse Code Modulation
REM	Recovery Exercise Module

SAC	Strategic Air Command
SALT	Strategic Arms Limitation Treaty
SCAD	Subsonic Cruise Armed Decoy
SECDEF	Secretary of Defense
SLBM	Sea Launched Ballistic Missile
SLCM	Sea Launched Cruise Missile
TAAM	Tomahawk Airfield Attack Missile
TASM	Tomahawk Anti-Ship Missile
TLAM-A	Tomahawk Land Attack Missile (Nuclear)
TLAM-C	Tomahawk Land Attack Missile (Conventional)
TLAM-D	Tomahawk Land Attack Missile (Multiple Payloads)
TEL	Transporter Erector Launcher
TEMP	Test and Evaluation Master Plan
TERCOM	Terrain Contour Matching
TTP	Transition to Production
UFC	Unit Flyaway Cost
VLS	Vertical Launch System
WIC	Williams International Corporation
WPAFB	Wright Patterson Air Force Base

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